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CAVITY-TREE SELECTION BY RED-COCKADED WOODPECKERS AS RELATED TO GROWTH DYNAMICS OF SOUTHERN PINES

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Abstract.—We compared measurements at 212 Red-cockaded Woodpecker (*Picoides borealis*) cavity trees and 150 randomly selected mature pines in eastern Texas. Discriminant analyses indicated that cavity trees were significantly older and taller, with greater crown depths, volumes, and weights, and larger diameters at breast height than were randomly selected mature pines. Examination of growth increment cores indicated that cavity trees had undergone a period of suppressed growth after which they were released by some type of natural or man-caused thinning. Because shelterwood cutting imitates the suppression and release phenomenon we observed, we suggest that this harvest technique be used instead of clearcutting in areas around woodpecker colonies in order to provide an immediate and sustained supply of potential cavity trees. *Received 30 Sept. 1986, accepted 22 Jan. 1987.*

Red-cockaded Woodpecker (*Picoides borealis*) colonies in eastern Texas have decreased in number over the past 30 years (D. W. Lay, pers. comm.). Declines and extirpation of active colonies also continue elsewhere (Thompson 1976; Baker 1983; M. A. Byrd, pers. comm.; J. A. Jackson, pers. comm.; R. F. Labisky, pers. comm.). The recovery of endangered species should include a demonstrated population increase. Because the Red-cockaded Woodpecker is a cooperative breeder, a true recovery must include an increase in the number of breeding units (clans or colonies). The fact that we are not observing the formation of new colonies by pioneering or budding (Hooper 1983) throughout the Red-cockaded Woodpecker's range suggests that our management may be inadequate and that alternative management techniques may be needed, particularly for populations (demes) where fewer than 250 colonies exist (see Franklin 1980).

Most studies on Red-cockaded Woodpeckers have focused on descriptions of nesting habitat (Lay and Russell 1970, Ligon 1970, Morse 1972, Grimes 1977), foraging habitat (Ligon 1968, Morse 1972, Skorupa and McFarlane 1976, Nesbitt et al. 1978, Hooper and Lennartz 1981), and home-range size (Baker 1971, Skorupa and McFarlane 1976, Hooper et al. 1982, Nesbitt et al. 1982). A few studies have examined specific characteristics of pine trees, such as age, presence of heartwood decay, and

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growth form, that are important to the species and perhaps serve as search images for cavity-tree selection (Thompson 1971, Jackson 1977b, Jackson et al. 1979, Conner and Locke 1982, Locke et al. 1983). Recently, Field and Williams (1985) have suggested that the importance of age is questionable.

Because Red-cockaded woodpeckers nest in live cavity trees that actively ooze oleoresins at resin wells, the amount of resin a cavity tree can produce may also be an important characteristic for the woodpeckers. Classic studies in naval stores (turpentine industry) indicate that crown characteristics and vigor of pines are related to the production of oleoresins (Wahlenberg 1946). Growth history of cavity trees may also be important to cavity-tree selection because it can affect tree appearance and wood structure.

We examined differences among 212 Red-cockaded Woodpecker cavity trees and 150 randomly selected mature pines. Our objectives were to (1) determine if Red-cockaded Woodpeckers selected specific pine trees for cavity excavation and (2) identify any special characteristics of the cavity trees that may relate to stand management techniques necessary to grow such trees.

STUDY AREA

The Angelina National Forest (Angelina, Jasper, Nacogdoches, and San Augustine Counties) includes 62,423 ha of forested lands in eastern Texas. Approximately 49% of this forest is northeast of Sam Rayburn Reservoir, and 51% is southwest. Red-cockaded Woodpeckers in the northeast portion of the Angelina National Forest are found in stands comprised mainly of loblolly (*Pinus taeda*) and shortleaf (*P. echinata*) pines. Those to the southwest are primarily in longleaf (*P. palustris*) pine forests. Active colonies northeast of the reservoir are a minimum of 34 km from active colonies to the southwest.

METHODS

We searched for, located, and tagged 212 Red-cockaded cavity trees during 1983 and 1984. Two people examined each tree in mid-April (the beginning of the nesting season) and concurred on whether the tree was active or not. We judged resin wells to be active if the bark bordering the well was red (indicating recent pecking [Jackson 1978a]), and clear, fresh resin was flowing from the well. Cavity trees without any active resin wells were considered inactive (Jackson 1977a). We examined cavity trees closely from all sides to ensure that fresh resin or reddish bark around wells was not the result of Pilcated Woodpecker (*Dryocopus pileatus*) activity (early stages of cavity enlargement and foraging sites, which are common), Cerambycid beetle oviposit sites, Yellow-bellied Sapsucker (*Sphyrapicus varius*) feeding sites, or injury.

A noncavity tree was selected by walking a varying predetermined distance into stands and using a board-game spinner device to indicate the tree to be selected. If an obviously young tree was indicated, the spinner was spun again. Four or 5 of the most mature noncavity-tree pines were selected within 37 stands of mature pine forest for comparisions with cavity trees. We selected the 37 most mature forest stands available using National Forests of

Texas continuous inventory of stand conditions (CISC) data for the Angelina National Forest. To reflect the relative proportions of cavity-tree species, 26 of the 37 stands were longleaf pine and 11 loblolly and shortleaf pine. All stands where we randomly selected mature pines were at least 150 m from Red-cockaded Woodpecker cavity trees, but still within areas potentially frequented by woodpeckers during foraging activities.

We measured characteristics of 212 cavity trees (during the summer of 1984) and 150 randomly selected trees (spring 1985), as well as the habitat immediately surrounding them (Table 1). We extracted 5 mm-diameter increment cores from pines at breast height and used a binocular dissecting scope to count annual growth rings. Three years were added to the number of increments for loblolly and shortleaf pines and 5 years to longleaf pines to determine the age of trees from the time they germinated (L. C. Walker, pers. comm.). We were unable to age 22 of the cavity trees because the heartwood at breast height was decayed. Each core was examined for signs of suppression or stress as indicated by tightly packed growth rings; it was judged that suppression had occurred if there was a growth rate of ≥ 16 growth rings/cm for a period of 5 years or longer. We noted the total number of contiguous years that each tree was suppressed, as well as the age of the tree if and when a release (as indicated by sudden return to large growth increments) occurred. The percentage of years that each tree had been growing under suppressed conditions was calculated. The number of growth increments in the outer 2 cm of each pine's sapwood was measured to evaluate recent growth trends.

We determined crown shape (conical, parabolic, cylindrical), measured the drip line, and estimated what portion of the crown was present (for asymmetrical crowns), and from these values we calculated a crown volume for each tree. Crown weights (branch wood, branch bark, needles) were calculated from tree height and diameter at breast height (DBH) measurements (see Taras and Clark 1975, 1977; Clark and Taras 1976). Crown depth was measured as the vertical distance between the top of the crown and the lowest major branches on the bole of the tree. Tree and midstory height were measured with a clinometer. Bole length was determined by subtracting crown depth from tree height. Bark thickness (cm) was measured at breast height. Basal areas were measured with a 1-factor metric prism, using each cavity tree or randomly selected pine as the center of the sampling point.

We used a 2-tailed *t*-test to compare characteristics of cavity trees with those of the randomly selected mature pines (random pines). Discriminant function analysis (DFA) was used to evaluate differences between cavity trees and random pines. Correlations of original variables to the discriminant axes were used to evaluate the importance of variables to the discrimination (Bargmann 1970, Timm 1975).

RESULTS

Red-cockaded Woodpecker cavity trees differed from randomly selected mature pines on the Angelina National Forest (Table 1). Regardless of whether tree species were combined or examined separately, Red-cockaded Woodpecker cavity trees were older and taller, with greater crown depths, volumes, and weights, larger diameters at breast height, and slower recent growth than were random pines. Within tree species groups, bark thickness of cavity trees was greater than that of the random pines (Table 1).

Because many tree characteristics, especially the crown and tree size, are usually correlated with tree age, some differences we detected between

TABLE 1

COMPARISONS OF VARIABLE MEANS MEASURED AT AND AROUND RED-COCKADED WOODPECKER CAVITY TREES AND RANDOMLY SELECTED MATURE PINES IN THE ANGELINA NATIONAL FOREST IN EASTERN TEXAS

Variables	Longleaf pines		Loblolly and shortleaf pines		All pine species	
	Cavity trees (N = 151)	Random pines (N = 97)	Cavity trees (N = 61)	Random pines (N = 53)	Cavity trees (N = 212)	Random pines (N = 150)
Tree						
Age (year)[a]	126.4	56.7[b]	86.9	61.2[b]	114.5	58.3[b]
Crown depth (m)	9.5	6.1[b]	9.0	7.0[b]	9.4	6.4[b]
Crown volume (m^3)	405.7	129.7[b]	419.6	221.0[b]	409.7	162.7[b]
Crown weight (kg)	450.5	237.7[b]	555.8	328.8[b]	480.8	271.2[b]
Diameter at breast height (cm)	47.5	36.3[b]	52.7	41.5[b]	49.0	38.2[b]
Tree height (m)	24.2	22.9[c]	28.1	26.0[b]	25.4	24.0[d]
Bole length (m)	14.7	16.8[b]	19.1	18.9[e]	16.0	17.6[b]
Bark thickness (cm)	1.9	1.8[f]	2.3	1.9[d]	2.1	1.8[d]
No. growth increments in last 2 cm	17.1	12.7[b]	13.6	11.5[f]	16.1	12.3[b]
Stand						
Total basal area (m^2/ha)	15.8	19.6[b]	16.3	23.9[b]	15.9	21.2[b]
Basal area of pine overstory (m^2/ha)	14.1	17.2[b]	13.7	16.9[b]	14.0	17.1[b]
Basal area of pine midstory (m^2/ha)	1.1	1.6[e]	1.1	2.2[c]	1.1	1.8[c]
Basal area of hardwood overstory (m^2/ha)	0.2	0.1[f]	0.3	0.3[e]	0.2	0.2[e]
Basal area of hardwood midstory (m^2/ha)	0.4	0.8[f]	1.1	4.5[b]	0.6	2.1[b]
Midstory height (m)	2.9	5.1[b]	5.6	8.1[c]	3.7	6.2[b]

[a] See Table 2 for sample size—some cavity trees were decayed in center.
[b] *t*-test, $P < 0.0001$.
[c] *t*-test, $P < 0.01$.
[d] *t*-test, $P < 0.001$.
[e] Not significantly different, $P > 0.05$.
[f] *t*-test, $P < 0.05$.

cavity trees and the random pines could have been related to cavity tree age. Our comparision of cavity trees and random trees of similar ages (the subset of 80–100 year-old longleaf pines was the only age and species group with sufficient sample size; there were 87 degrees of freedom) indicated that crown depth (*t*-test, $P < 0.0001$), crown volume ($P < 0.001$), crown weight ($P < 0.001$), and diameter at breast height ($P < 0.001$) were greater for cavity trees than random pines. Average age of the cavity trees in this subset of trees was 97-years-old, and random trees averaged 91-years-old ($P < 0.05$). Thus, even in this subset, tree age was significantly different although to a much lesser degree than crown measurements. We detected no significant differences in tree height and bark thickness between 80 and 100-year-old cavity and random longleaf pines.

Stands immediately surrounding cavity trees had lower total basal area and basal area of pine overstory trees than stands around the random pines (Table 1). Within tree species groups, areas around cavity trees had lower hardwood midstory basal area and midstory height than areas around random pines.

Examination of increment cores showed that longleaf pine cavity trees had a longer average period of suppression, longer percentage of life suppressed, and older age at time of release than random longleaf pines (Table 2). More than 77% of longleaf pine cavity trees showed marked signs of suppression and release, whereas only 23.5% of random longleaf pines exhibited signs of suppression and release. When it was observed in the random trees, the transition between suppressed increments and released increments was much less obvious than in the cavity trees. Although suppression and release occurred in 56% of loblolly and shortleaf pine cavity trees and only 46% of random loblolly and shortleaf pines, we detected no significant differences in the duration of suppression, percentage of life suppressed, and age at time of release between cavity and random trees (Table 2). When all tree species were combined, results followed the same significance pattern observed for longleaf pines separately.

Most cavity trees germinated 40 years prior to the extensive wave of timber harvesting that swept through eastern Texas and peaked around 1910 (Maxwell and Baker 1983) (Fig. 1A). Whereas a sustained and gradual release of suppressed pines apparently occurred prior to 1890, the extensive harvesting from 1890 to 1930 may have provided the release for most of the cavity trees in existence on the Angelina National Forest today (Fig. 1B). The skewed nature of the distribution of cavity tree age (Fig. 1C) may reflect the removal of many existing older cavity trees by the surge of timber harvesting that occurred around the turn of the century. Most of the random pines on the Angelina National Forest germinated after the major timber harvests of the early 1900s (Fig. 1C). Relative to tree age, active cavity trees were a subset of all cavity trees (Fig. 1C and D). The youngest active cavity tree (64-years-old) germinated about 1921, whereas the youngest inactive cavity tree (45-years-old) germinated around 1940. The oldest active cavity tree (205-years-old) germinated in 1780, while the oldest inactive cavity tree (328-years-old) germinated in 1657.

Examination of cores from cavity trees indicated that they had grown

TABLE 2

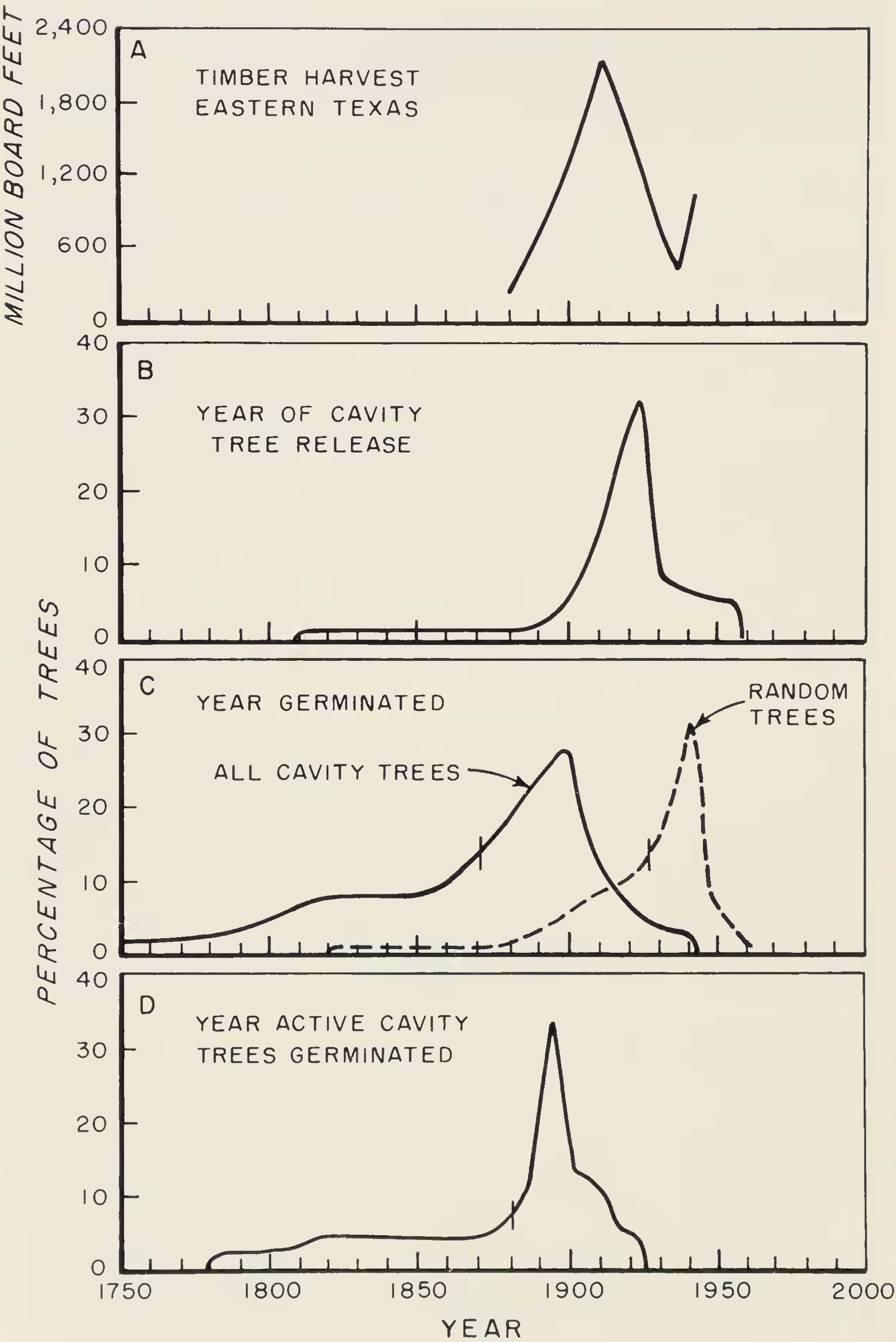
COMPARISONS OF VARIABLE MEANS MEASURED FROM INCREMENT CORES EXTRACTED AT BREAST HEIGHT FROM RED-COCKADED WOODPECKER CAVITY TREES AND RANDOMLY SELECTED MATURE PINES ON THE ANGELINA NATIONAL FOREST IN EASTERN TEXAS

	Longleaf pines		Loblolly and shortleaf pines		All pine species	
Variables	Cavity trees (N = 133)	Random pines (N = 97)	Cavity trees (N = 57)	Random pines (N = 52)	Cavity trees (N = 190)	Random pines (N = 150)
Age (years)	126.4	56.7[b]	86.9	61.2[b]	114.5	58.3[b]
Duration of suppression (years)	48.2	6.7[b]	9.6	7.8[c]	36.6	7.1[b]
Percent of life suppressed	31.4	7.3[b]	10.5	11.4[c]	25.1	8.7[b]
Year germinated	1857	1928[b]	1898	1924[b]	1870	1926[b]
Year released	1919	1949[b]	1926	1948[b]	1921	1949[b]
Age of release (years)	72.2	40.7[d]	31.2	29.0[c]	62.5	34.7[b]
Number of trees showing suppression and release	103	23	32	24	135	47
Percent of trees showing suppression and release	77.4	23.5	56.1	46.2	71.1	31.3

[b,d,c] See footnotes in Table 1.

under two general conditions. Most of the older cavity trees (120–328 years old, N = 65) had probably begun their initial growth within an older forest stand. They were suppressed from the day they germinated—one had been suppressed for 200 years. Eventually these trees were released by some type of natural or human-caused thinning of overstory trees. The released trees began to grow vigorously, filled out their crowns somewhat, and eventually were selected by Red-cockaded Woodpeckers for cavity excavation. The above pattern of growth suggests that these cavity trees may have grown up in an uneven-aged forest or were subdominant in small even-aged stands (Chapman 1909).

Most of the cavity trees younger than 120-years-old were not suppressed when they first germinated. Their initial growth was vigorous as demonstrated by widely spaced growth increments. A gradual decrease in the spacing of rings when the trees were 15–25-years-old indicated that as these trees matured, suppression began with competition for light, moisture, etc. These future cavity trees were subsequently released by some sort of thinning, and vigorous growth ensued. This pattern of growth suggests an even-aged forest stand where pines became suppressed when the canopy closed but were later released by some type of thinning.


MILLION BOARD FEET
2,400
1,800
1,200
600
0
A
TIMBER HARVEST
EASTERN TEXAS
40
30
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0
B
YEAR OF CAVITY
TREE RELEASE
C
YEAR GERMINATED
RANDOM
TREES
ALL CAVITY TREES
D
YEAR ACTIVE CAVITY
TREES GERMINATED
PERCENTAGE OF TREES
1750
1800
1850
1900
1950
2000
YEAR

Discriminant function analyses (contrasting cavity trees with randomly selected mature pines) indicated that tree age, diameter at breast height, and crown characteristics were variables that accounted for the greatest differences between cavity trees and the random pines (Table 3). These characteristics transcended tree species. In general, characteristics of individual trees (such as age, DBH, and crown variables) had greater importance for discrimination between cavity trees and random trees than did stand characteristics (basal area measurements). In all three DFA's, discrimination of cavity trees from random trees was very highly significant, and subsequent classification of trees into the correct group exceeded 90%.

An additional DFA, using only data from tree cores to compare all cavity trees with all random trees (N = 190 and N = 150, respectively; $P < 0.0001$; 87% of cases classified correctly), indicated that tree age ($r = 0.64$, $P < 0.001$), age of release ($r = 0.34$, $P < 0.01$), duration of suppression ($r = 0.33$, $P < 0.01$), and percentage of life suppressed ($r = 0.18$, $P < 0.01$) were significantly correlated to the discriminant axis and were the most important variables discriminating between cavity and random trees.

DISCUSSION

Red-cockaded Woodpeckers used cavity trees that averaged more than 55 years older than the random pines (Table 1). Although Field and Williams (1985) suggest otherwise, age *is* a very important factor for a variety of reasons. Pines younger than 50-years-old typically have very little heartwood; most of the tree is composed of sapwood (Koch 1972). Thus, only older trees usually have enough heartwood to house a cavity. Sapwood probably is unsuitable for cavity excavation because its living cells actively ooze oleoresins. Resins flowing from sapwood could soon render a nest cavity unusable, particularly in healthy pines. Heartwood is composed of only dead plant cells and thus does not actively ooze resin. Also, the older the tree, the wider the heartwood is in higher regions of the tree; thus cavities may be excavated higher in the tree. High nest cavities may be particularly important if resin flow from resin wells is not to be ignited by prescribed or natural fire (Conner and Locke 1979). High cavities may also be more difficult for rat snakes (*Elaphe obsoleta*) to reach than are low cavities. Dennis (1969) observed that the average

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FIG. 1. Timber harvest in eastern Texas (A) shown in relation to year of cavity tree release (B), year in which cavity and random trees germinated (C), and year in which active cavity trees germinated (D).

TABLE 3

RESULTS OF THREE DISCRIMINANT FUNCTION ANALYSES (DFA) CONTRASTING RED-COCKADED WOODPECKER CAVITY TREES WITH RANDOMLY SELECTED MATURE PINES ON THE ANGELINA NATIONAL FOREST IN EASTERN TEXAS

	Longleaf pines	Loblolly and shortleaf pines	All pine species
DFA results			
N for cavity trees	151	61	212
N for random pines	97	53	150
$\bar{x}$ for cavity tree group	1.14	1.24	1.13
$\bar{x}$ for random pine group	−1.17	−1.43	−1.61
Overall DFA significance	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
% of cases correctly classified	92	90	92
Correlation[a] of original variables to the discriminant axis			
Tree age	0.62	0.61	0.58
Diameter at breast height	0.57	0.59	0.54
Crown weight	0.31	0.51	0.39
Crown depth	0.40	0.23	0.38
Crown volume	0.37	0.23	0.36
Total basal area		−0.56	−0.34
Basal area pine overstory		−0.43	−0.22
Tree height		0.27	
Basal area hardwood midstory		−0.24	−0.25
Bark thickness		0.23	

[a] Only correlations with $P < 0.01$ are included.

height of successful nests of Northern Flickers (*Colaptes auratus*) was greater than the average height of unsuccessful nests.

Older trees often have heartwood decaying fungi that decay and soften the heartwood of prospective cavity trees (Steirly 1957, Jackson 1977b, Conner and Locke 1982). Cavities in trees with a decayed heartwood are more easily excavated because the wood tissue is physically easier to chisel out. The extremes of time required to excavate cavities by Red-cockaded Woodpeckers (less than 4 months, R. A. Beck, pers. comm.; 1 year or more, Jackson 1977b) may reflect the time required for excavation of cavities in pines with and without heartwood decay. The incidence of heartwood decay in southern pines is related to tree age and stress (Wahlenberg 1946, 1960). Nelson (1931) reported the frequencies of heartwood decay in various age groups of loblolly pines: 40–90-years-old, 5.4% with heartrot; 91–140-years-old, 18.6%; 141–190-years-old, 60%; 191–230-years-old, 72.2%. Wahlenberg (1946, 1960) considered the frequency of heartwood decaying fungi to be low in loblolly pines less than 75-years-old and longleaf pines less than 100-years-old.

Old pine trees may be important to Red-cockaded Woodpeckers for yet another reason. Resin wells kept active by woodpecker pecking may deter predators such as the gray rat snake (*Elaphe obsoleta spiloides*) (Dennis 1971; Jackson 1974, 1978b). Resin flowing from resin wells eventually loses its gummy quality and hardens, becoming of little use in deterring rat snakes (Jackson 1978b). Old pines have slower resin crystallization rates than do younger pines (Hodges et al. 1977). Thus, resin from resin wells in old pine trees will remain sticky and keep its deterrent quality longer than resin from younger pines.

Cavity trees exhibited the phenomenon of suppression and then release significantly more than did random pines. Although the suppression-release phenomenon could be an artifact of tree age, suppression may also lead to characteristics conducive to cavity excavation that are independent of age. For example, suppression may cause lower limbs to be dropped, cause additional heartwood to form, or make the tree more susceptible to fungal heartrot. Field observations of cavity trees suggest that Red-cockaded Woodpeckers prefer trees with clear boles up to the region of the tree where cavities are excavated (Locke et al. 1983, R. N. Conner, pers. obs.; J. A. Jackson, pers. comm.; D. W. Lay, pers. comm.). The clear tree bole may help prevent rat snakes from climbing cavity trees.

Following suppression and release, precavity trees apparently return to fairly vigorous growth as indicated by greatly increased distances between growth increments. The return to vigorous growth also may be indicated by the significantly larger crowns of cavity trees in contrast to random pines (Table 1). Woodpecker selection of trees with large crowns again may relate to oleoresin production. Bushy, heavy-topped longleaf pines have been observed to yield 40% more resin than do pines with smaller crowns (Wahlenberg 1946). Borrowing from James' (1971) concept of habitat "Gestalt," Red-cockaded Woodpeckers may search for cavity trees with an open bole and a large crown.

Nearly all pines grown in a forest stand will eventually be suppressed unless some type of thinning or cutting occurs. In natural stands, insects, disease, or fire often provide a release for surviving trees to return to more vigorous growth. The sudden release and return to relatively vigorous growth noticed in Red-cockaded Woodpecker cavity trees was not widely observed in the random pines and would not be the typical growth pattern in most short-rotation, even-aged managed forests because such trees are typically clearcut.

During the later stages of the Red-cockaded Woodpecker cavity tree's life, growth again slowed down as indicated by the number of growth increments in the outer 2 cm of sapwood (Table 1). Much of this decrease in growth rate may relate to senescence, but we suspect that additional growth-retardant stress may be caused by woodpecker excavation and maintenance of resin wells.

We detected that woodpecker cavity trees were in stands with significantly lower basal area and less hardwood midstory than were random pines (see Jackson 1971, Hooper et al. 1980, Lennartz et al. 1983, Hovis and Labisky 1985) (Table 1). A release of the suppressed "precavity" tree may be necessary to create the open, low basal area stands that Red-cockaded Woodpeckers apparently prefer around their cavity trees (Jackson 1971, Hooper et al. 1980, Lennartz et al. 1983, Locke et al. 1983). The DFA's we calculated indicated that cavity tree variables such as age, diameter at breast height, and crown size were more important to the discrimination between cavity and random trees than were stand variables such as basal area and amount of hardwood midstory (Table 3). These observations suggest that individual tree characteristics may be of greater importance in Red-cockaded Woodpecker habitat selection than general forest stand characteristics.

MANAGEMENT IMPLICATIONS

Timber management that results in suppressed tree growth followed by a release from suppression should result in suitable Red-cockaded Woodpecker cavity trees. An existing silvicultural system that might mimic the conditions that apparently produced the trees chosen as cavity trees in eastern Texas today is the shelterwood method. Although a shelterwood reproduction cut harvests most trees, it leaves some selected mature pines standing to provide seeds and shelter for the next generation of pines (Society of American Foresters 1981). This harvesting technique would permit the release of unharvested mature pines from relatively dense, stressed stands to grow with greater vigor, fill out their crowns and provide a prompt supply of potential cavity trees.

A modified shelterwood cut of 80-year-old longleaf pines or a thinning cut to a basal area of about 9 m^2/ha (75 mature pines/ha) offers a harvest management option of potential value to Red-cockaded Woodpeckers. We suggest a pine basal area of 9 m^2/ha because it is the upper limit for a shelterwood cut (Society of American Foresters 1981) and about the lower limit of basal area (9–14 m^2/ha) for quality Red-cockaded Woodpecker habitat (Hooper et al. 1980). Because the current zone suggested for Red-cockaded Woodpecker recruitment stands is between 400 and 1200 m of an active colony (U.S.D.A. 1984), shelterwood or thinning cuts should be used in pine stands that are within 1200 m of active woodpecker colonies for maximum potential recruitment of new colonies. After shelterwood trees have grown to about 120-years-old, their removal could be considered if they have not been colonized by woodpeckers. Leaving shelterwood trees to provide foraging habitat until they die should also be considered.

Use of shelterwood cuts such as we describe would eliminate the problems encountered when trying to determine where recruitment stands need to be placed. At present, it is often difficult for wildlife managers to find appropriately aged stands at the correct distances from active woodpecker colonies. Shelterwood cut areas would be available for both recruitment of new colonies and for foraging habitat.

Historically and recently, southern pine beetles (*Dendroctonus frontalis* Zimm.) have killed extensive areas of pine forest in the South (Thatcher et al. 1980, Kulhavy and Conner 1986). Pine beetle infestations can kill Red-cockaded Woodpecker cavity trees if colonies are in dense pine stands (Jackson et al. 1986). Shelterwood cuts would greatly reduce timber stand density and, thus, reduce the hazard of beetle infestation in stands around cavity trees.

Red-cockaded Woodpeckers have declined in abundance in the past 30 years (Thompson 1971, Wood 1983). Although recent research suggests that clearcutting may not cause an increase in territory size or immediate declines in nesting success (Wood et al. 1985), the effects of clearcutting are still poorly documented (Thompson 1976). The decline of the woodpecker during a period when clearcutting is the usual management method does not speak well of its effect on Red-cockaded Woodpeckers. Our proposed management strategy and other alternatives should be implemented on an experimental basis. Input from silviculturists is needed to develop a complete management plan that permits a sustained yield of both Red-cockaded Woodpecker habitat and timber. As with any wildlife-timber management practice, its effects should be evaluated prior to widespread implementation.

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